NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2776

THE EFFECT OF A SIMULATED PROPELLER SLIPSTREAM ON THE AERODYNAMIC CHARACTERISTICS OF AN UNSWEPT WING PANEL WITH AND WITHOUT NACELLES AT MACH NUMBERS FROM 0.30 TO 0.86

By Gareth H. Jordan and Richard I. Cole

Langley Aeronautical Laboratory
Langley Field, Va.

Washington
September 1952

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 2776

THE EFFECT OF A SIMULATED PROPELLER SLIPSTREAM ON THE AERODYNAMIC CHARACTERISTICS OF AN UNSWEPT WING PANEL WITH AND WITHOUT NACELLES AT MACH NUMBERS FROM 0.30 TO 0.86

By Gareth H. Jordan and Richard I. Cole

SUMMARY

Force tests have been made in the Langley 24-inch high-speed tunnel in order to determine the effect of a simulated propeller slipstream on the aerodynamic characteristics of an unswept wing panel with and without nacelles. The lift, drag, and pitching moment were measured at angles of attack of 0° and 3° through a range of Mach numbers from approximately 0.30 to 0.86. The test results obtained for Mach numbers of the simulated propeller slipstream equal to and 10 percent greater than free stream indicated no significant changes in lift and pitching-moment coefficients for the configurations investigated. The Mach number for drag rise near zero lift was decreased approximately 0.02 as a result of the increase in propeller-slipstream velocity.

INTRODUCTION

The effect of a propeller slipstream on the aerodynamic characteristics of wing and wing-nacelle configurations at Mach numbers near the critical value has been a recurring question to aircraft designers. A simple test setup was made in the Langley 24-inch high-speed tunnel in order to determine the general effect of a simulated propeller slipstream on the aerodynamic characteristics of an unswept wing panel with and without nacelles. The propeller slipstream was simulated by a calibrated jet of air.

Forces were measured on an unswept wing panel with and without nacelles through a range of Mach numbers from 0.30 to approximately 0.86. Tests were made on the models at angles of attack of 0° and 3° with simulated slipstream Mach numbers equal to and 10 percent greater than free-stream values.

SYMBOLS

c	wing chord, ft
c_l	lift coefficient of wing panel, Lift/qS
$c_{m_{c/4}}$	quarter-chord pitching-moment coefficient of wing panel, Pitching moment/qSc
c_d	drag coefficient of wing panel, Drag/qS
M	free-stream Mach number
M_S/M	ratio of propeller-simulating jet Mach number to free-stream Mach number
q	free-stream dynamic pressure, lb/sq ft
S	wing-panel area, sq ft
α	angle of attack, deg
M_{DR}	Mach number for drag rise; Mach number at which $\frac{dc_d}{dM} = 0.1$
H	free-stream total pressure, lb/sq ft
H_l	total pressure at any specified location, lb/sq ft
p_l	static pressure at any specified location, lb/sq ft

APPARATUS AND TESTS

Tunnel and installation of model.- The investigation was made in the Langley 24-inch high-speed tunnel, which is an induction-type wind tunnel (ref. 1). An enclosure was recently constructed around the tunnel so that dry air from the induction nozzle would mix with air contained within the enclosure and thereby lower the water content of the induced air to a degree of dryness where condensation effects would be negligible. (See ref. 2.) The test section, which was originally circular, has been modified by the installation of flats on the tunnel walls. These flats reduced the width of the tunnel from 24 to 18 inches and changed the shape from circular to one more nearly approaching a rectangle.

The wing panels spanned the 18-inch dimension of the test section and passed through brass end plates that were mounted flush with the flat sides of the test-section wall. An end-plate arrangement was used that permitted forces to be transmitted without interference to the 3-component recording balance and that minimized the effects of air flow through the end-plate gap. The propeller slipstream was simulated by a jet of air flowing from a 3-inch-diameter calibrated jet centrally located in the tunnel. The angle of the jet from which the air flowed did not change angle of attack with the model. The exit of the slipstream jet was three-quarter wing chord upstream of the leading edge of the wing.

Models.- The profiles of the three model configurations that were investigated and their positions in relation to the propeller-slipstream simulating jet are shown in figure 1(a). The profile of the wing panel was a 3-inch-chord, NACA 64_1A012 airfoil section (ref. 3) and the nacelle was a 5-inch-long prolate spheroid with a fineness ratio of 5. The three configurations tested were the wing alone, the wing with the nacelle symmetrically alined, and the wing with an underslung nacelle. The center line of the underslung nacelle was one-eighth wing chord below and parallel to the wing chord. The wing alone was mounted so that its chord line at 0° angle of attack coincided with the center line of the jet. The two wing-nacelle configurations were mounted so that the center line of the nacelle and jet coincided at 0° angle of attack. In each case the jet exit was three-quarter wing chord upstream of the wing leading edge. The underslung nacelle configuration mounted in the Langley 24-inch high-speed tunnel is shown in figure 1(b).

Measurements.- Lift, drag, and pitching moment were measured on the three model configurations through a range of Mach numbers from 0.30 to the Mach number at which the tunnel choked (approx. 0.86). The Reynolds number of these tests varied from 5.1×10^5 at a Mach number of 0.30 to 11.2×10^5 at a Mach number of 0.86. Data were obtained at angles of attack of 0° and 3° and the change in angle of attack was made by rotating the models about the axis shown in figure 1(a).

The calibration of the tunnel and slipstream jet was made by measuring both total and static pressure across the tunnel test section at various stations downstream of the jet exit. Figure 2 shows the distribution of both total and static pressure across the tunnel at the wing-panel quarter-chord station for ratios of M_S/M of 1.0 and 1.1 at stream Mach numbers of 0.70 and 0.80. This distribution is typical of the distribution obtained for other stations along the chord of the wing panel and for other stream Mach numbers. For each test point, at a given free-stream Mach number, the jet total pressure was varied in order to obtain slipstream Mach numbers equal to and 10 percent greater than free stream. A ratio of M_S/M of 1.1 was considered to be the maximum value that might be expected at high Mach numbers in actual flight.

Accuracy.- The errors to which these data were subject were a result of inaccuracies in model installation, calibration of tunnel and jet air streams, balance, and reduction of test records. The random errors indicated by the test data are as follows:

Lift coefficient, c_l	±0.005
Drag coefficient, c_d	±0.0005
Quarter-chord pitching-moment coefficient, $c_{m_{c/4}}$	±0.002
Stream Mach number, M	±0.005

The correction for wind-tunnel-wall interference was not evaluated because of the unknown effect of the jet on the blockage and because of the preliminary nature of the data; this in no way would affect the conclusions drawn.

The choking phenomenon is an additional effect of tunnel walls, which causes large pressure gradients in the region of the model and results in questionable data at the highest Mach numbers. A Mach number range of 0.03 below the choking Mach number has been considered by other investigators to contain the principal effects of choking. The data in this range were, therefore, not faired through the test points.

RESULTS AND DISCUSSION

Lift coefficient.- The effect of a simulated propeller slipstream on the variation of lift coefficient with Mach number for the three configurations is shown in figure 3. The data for the wing alone (fig. 3(a)) show no effect on lift coefficient resulting from increasing the ratio of M_S/M from 1.0 to 1.1 at 0° angle of attack; however, at 3° angle of attack there is a small increase in the lift coefficient through a range of Mach numbers from 0.30 to 0.76. The lift break occurs at a Mach number of about 0.72 for ratios of M_S/M of both 1.0 and 1.1. For the symmetrically alined nacelle configuration (fig. 3(b)), the effect of a simulated propeller slipstream is similar to the effect previously mentioned for the wing alone; also, the underslung nacelle configuration (fig. 3(c)) indicates no change due to the increased ratio M_S/M, except for a greater divergence from zero lift for Mach numbers above 0.75 at 0° angle of attack.

Pitching-moment coefficient.- The variation of the pitching-moment coefficient with Mach number for simulated-propeller-slipstream Mach number to free-stream Mach number ratios of 1.0 and 1.1 is shown in figure 4. These data indicate no significant changes due to the increased ratio M_S/M in the pitching moment of any of the three configurations.

Drag coefficient.- Figure 5 presents the effect of a simulated propeller slipstream on the variation of drag coefficient with Mach number for the three configurations. The data for all configurations indicate that no change occurs in the drag coefficient because of the increase in the ratio M_S/M for stream Mach numbers from 0.30 to 0.70.

The Mach number for drag rise M_{DR} near zero lift is decreased approximately 0.02 as the ratio M_S/M is increased from 1.0 to 1.1. For an angle of attack of 3°, the effect of the increase in the ratio M_S/M is negligible.

The small effect of the simulated slipstream may be explained by the three-dimensional nature of the flow. If that part of the wing subjected to the simulated propeller slipstream (about 17 percent of span) did undergo the flow changes that are encountered in two-dimensional flows at a 10-percent higher Mach number, the force break would obviously occur much earlier than shown in these tests. The flow condition that does exist is a three-dimensional flow and is subject to a spanwise flow that relieves any localized low-pressure regions and, consequently, relieves any shock and separation effects that would have been expected from a two-dimensional concept that is too simplified.

CONCLUSIONS

A preliminary investigation was made in the Langley 24-inch high-speed tunnel in order to determine the effect of a simulated propeller slipstream on the aerodynamic characteristics of an unswept wing panel with and without nacelles at angles of attack of 0° and 3° for Mach numbers from 0.30 to approximately 0.86. The test results obtained with Mach numbers of the simulated propeller slipstream equal to and 10 percent greater than free stream Mach numbers indicated the following conclusions:

1. The increased velocity of the simulated propeller slipstream caused no significant changes in lift and pitching-moment coefficients for the configurations investigated.

2. The Mach number for drag rise near zero lift was decreased approximately 0.02 as a result of the increase in simulated-propeller-slipstream velocity for all configurations.

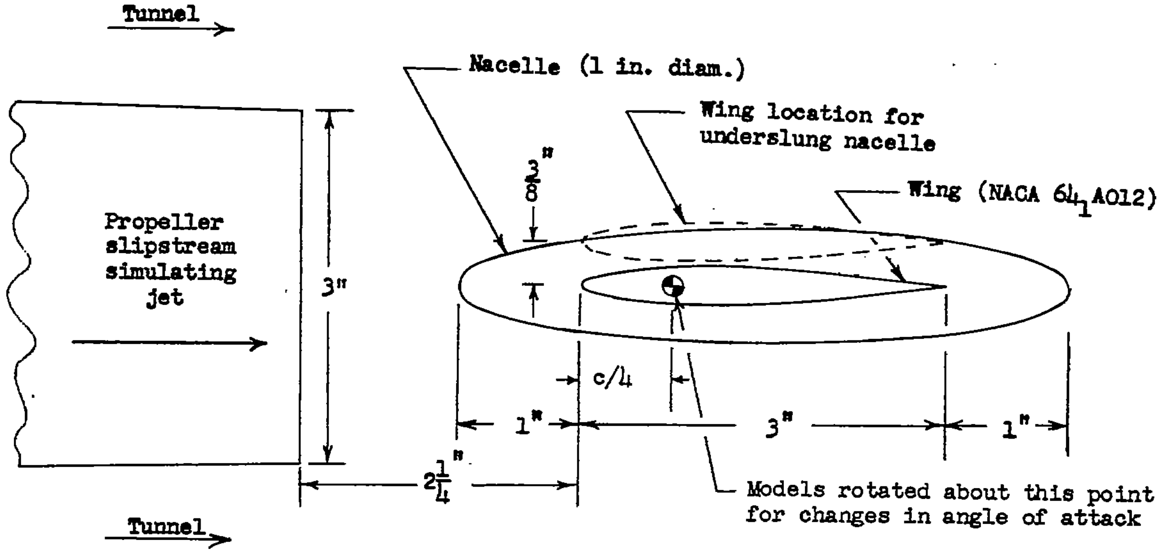
Langley Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 2, 1952

REFERENCES

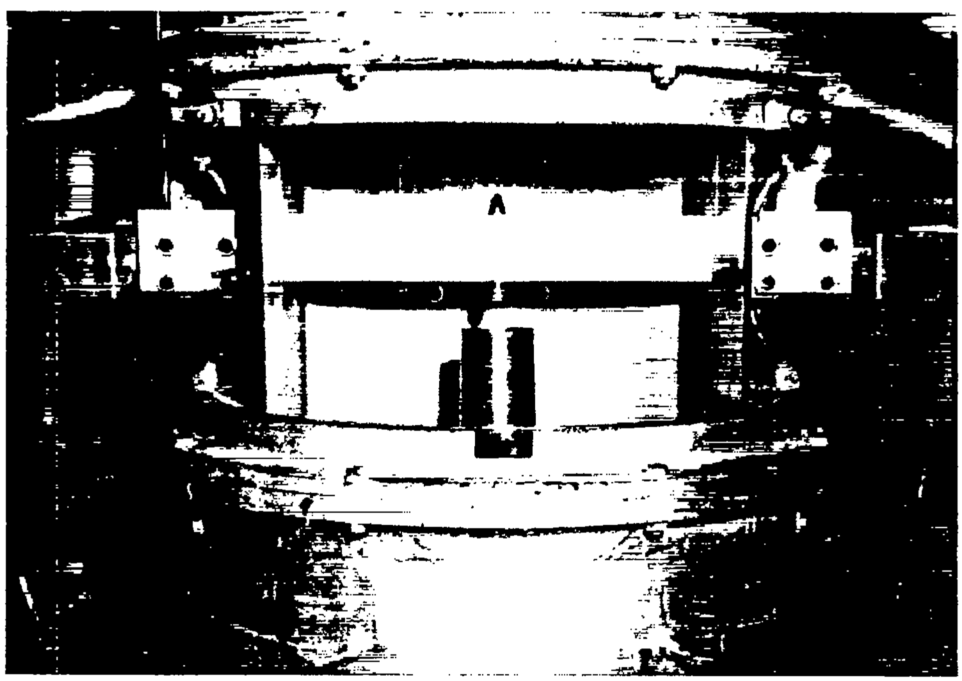
1. Stack, John, Lindsey, W. F., and Littell, Robert E.: The Compressibility Burble and the Effect of Compressibility on Pressures and Forces Acting on an Airfoil. NACA Rep. 646, 1938.

2. Lindsey, Walter F., and Chew, William L.: The Development and Performance of Two Small Tunnels Capable of Intermittent Operation at Mach Numbers Between 0.4 and 4.0. NACA TN 2189, 1950.

3. Loftin, Laurence K., Jr.: Theoretical and Experimental Data for a Number of NACA 6A-Series Airfoil Sections. NACA Rep. 903, 1948. (Supersedes NACA TN 1368.)



(a) Configuration profiles.



(b) Underslung configuration mounted in Langley 24-inch high-speed tunnel.

L-72591.1

Figure 1.- Configuration profiles and model installation.

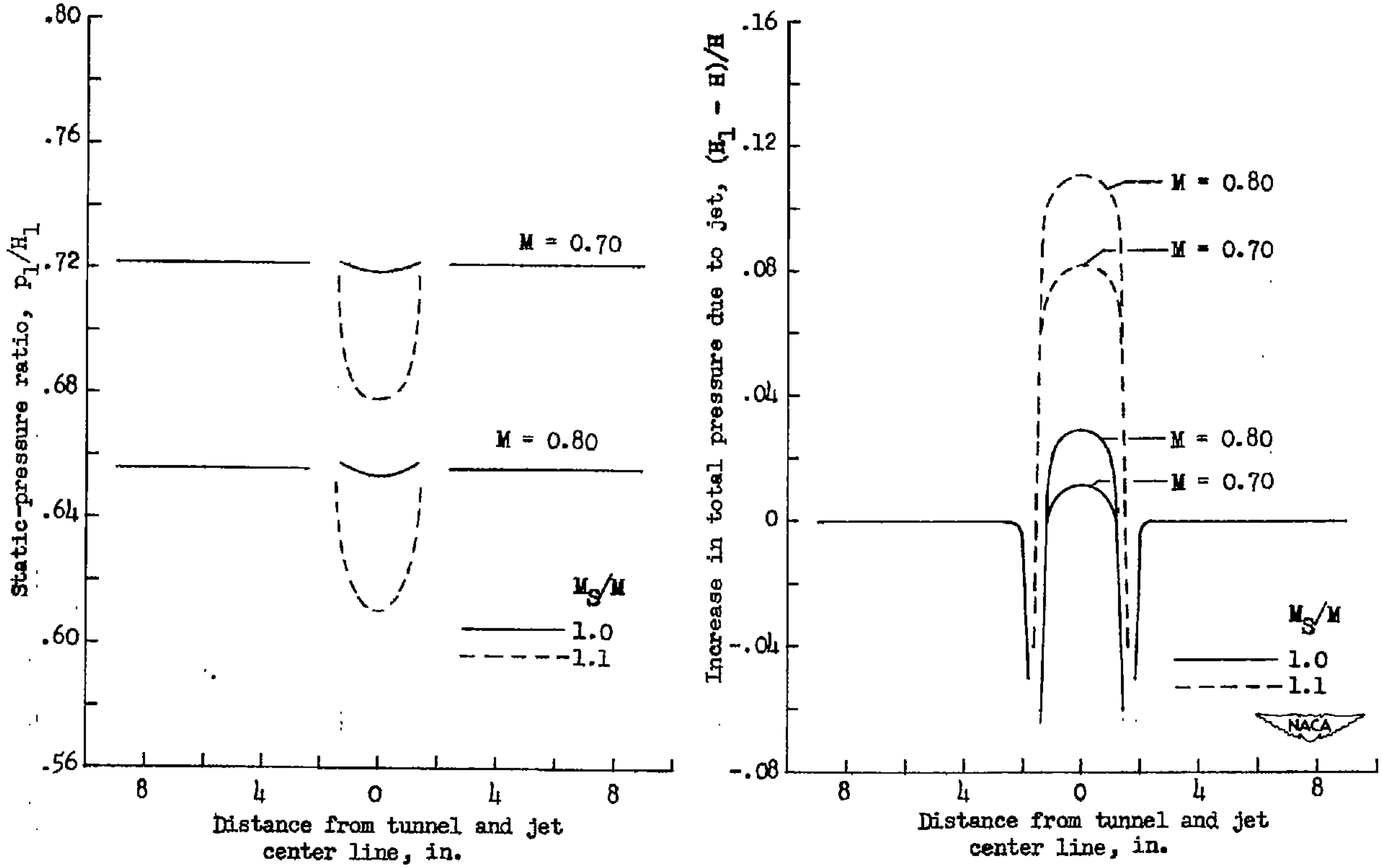
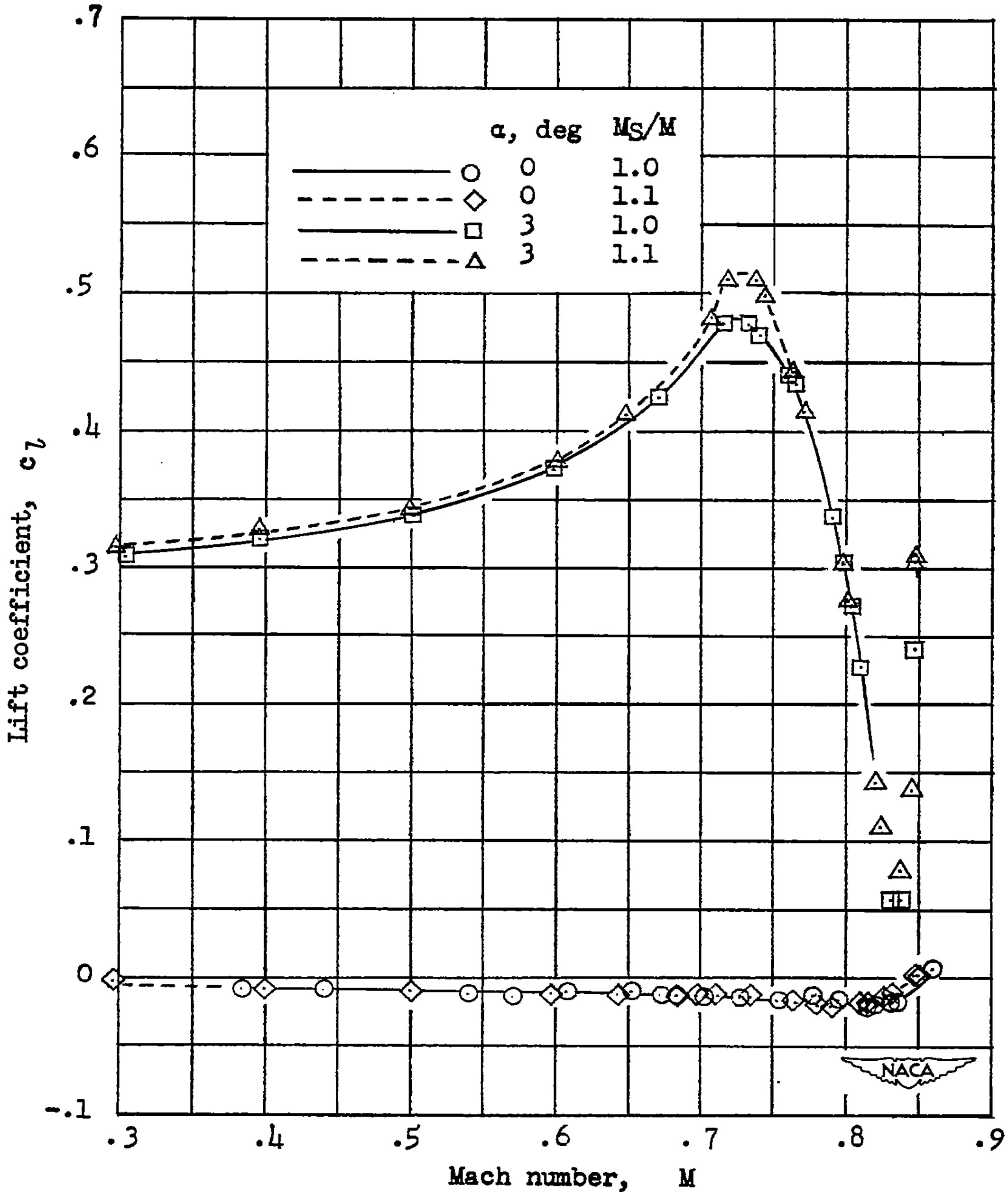
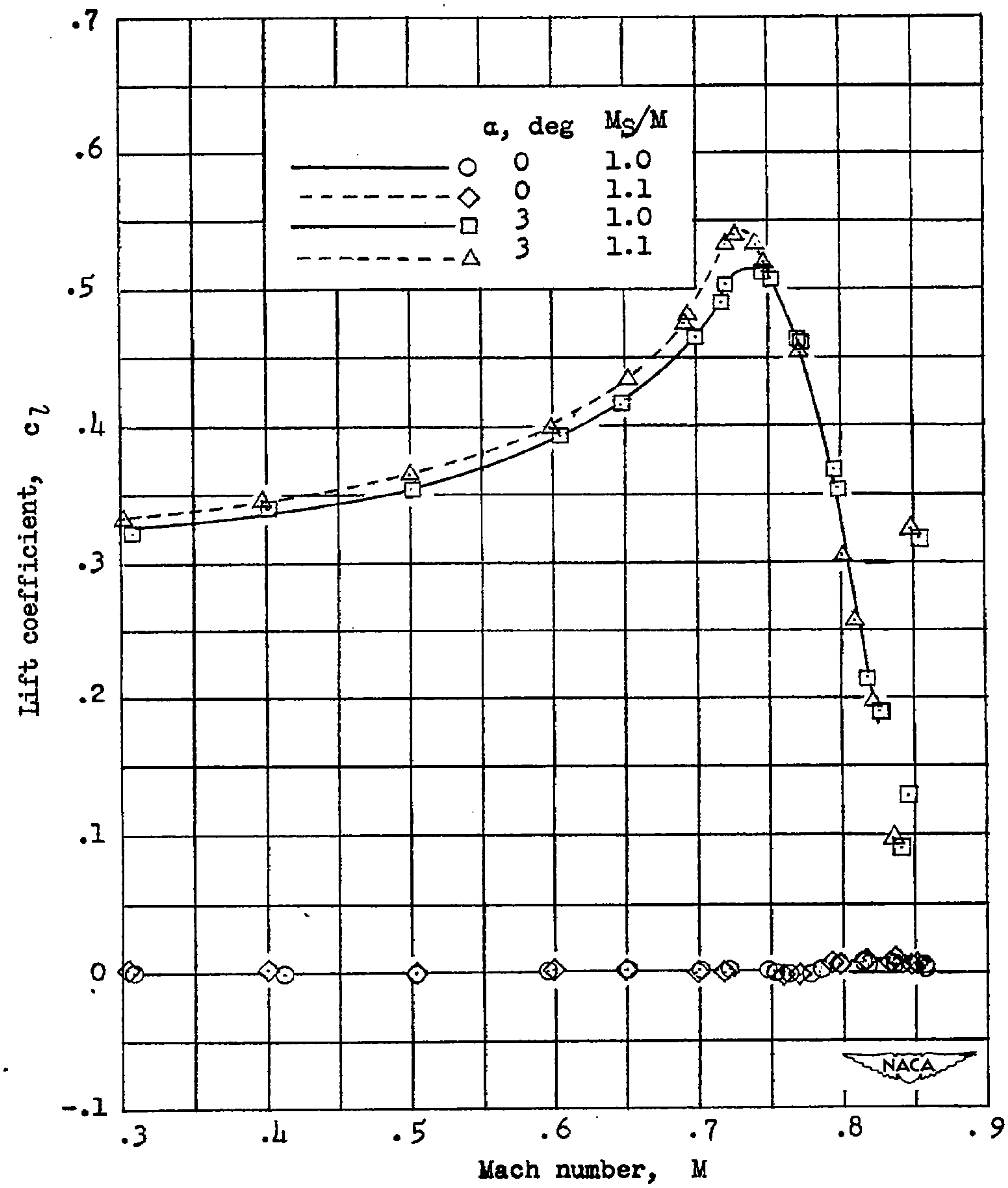


Figure 2.- Effect of jet on static-pressure distribution and total-pressure distribution across the Langley 24-inch high-speed tunnel at the quarter-chord position of the wing panel.



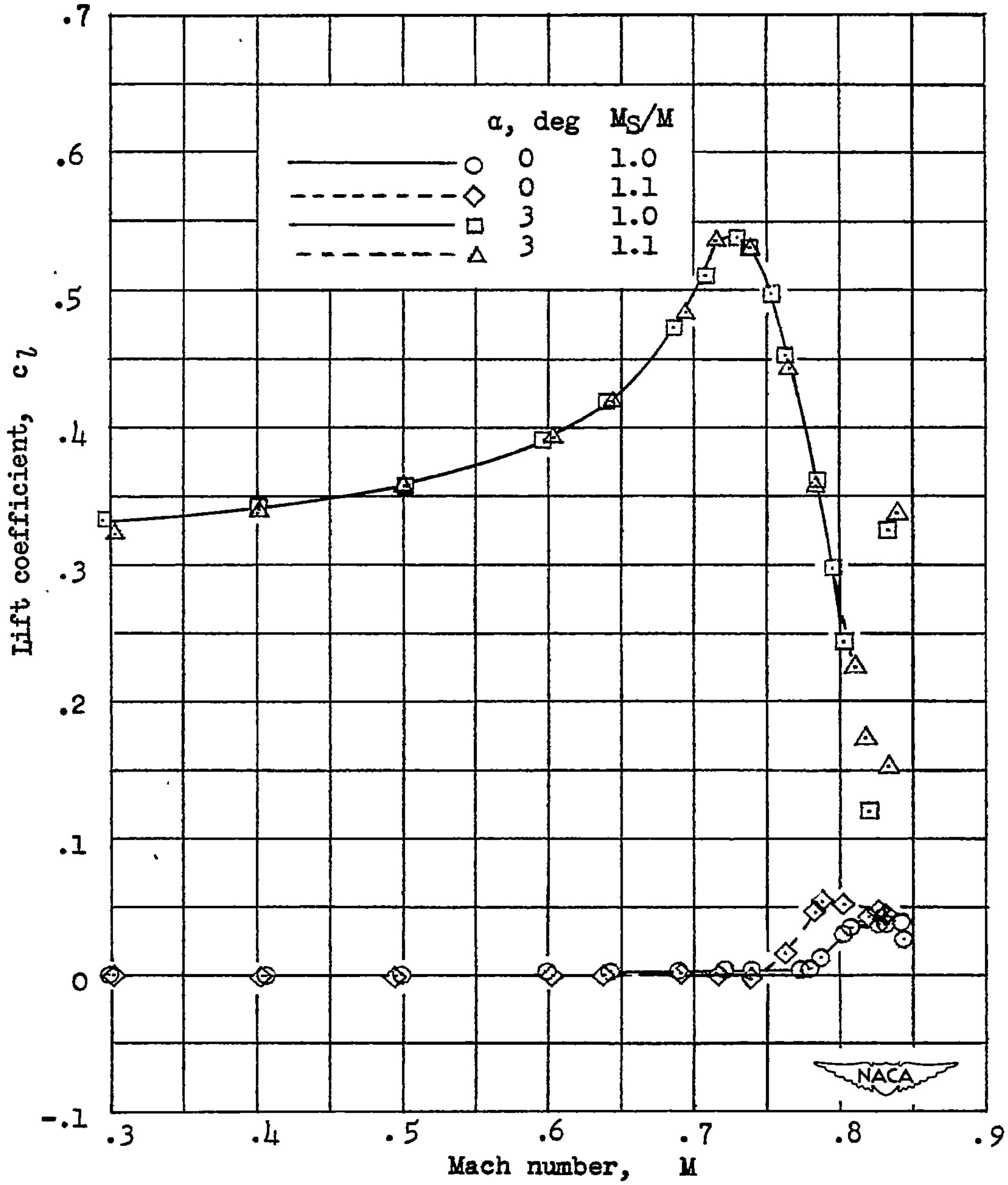
(a) Wing panel.

Figure 3.- Effect of slipstream on variation of lift coefficient with Mach number.



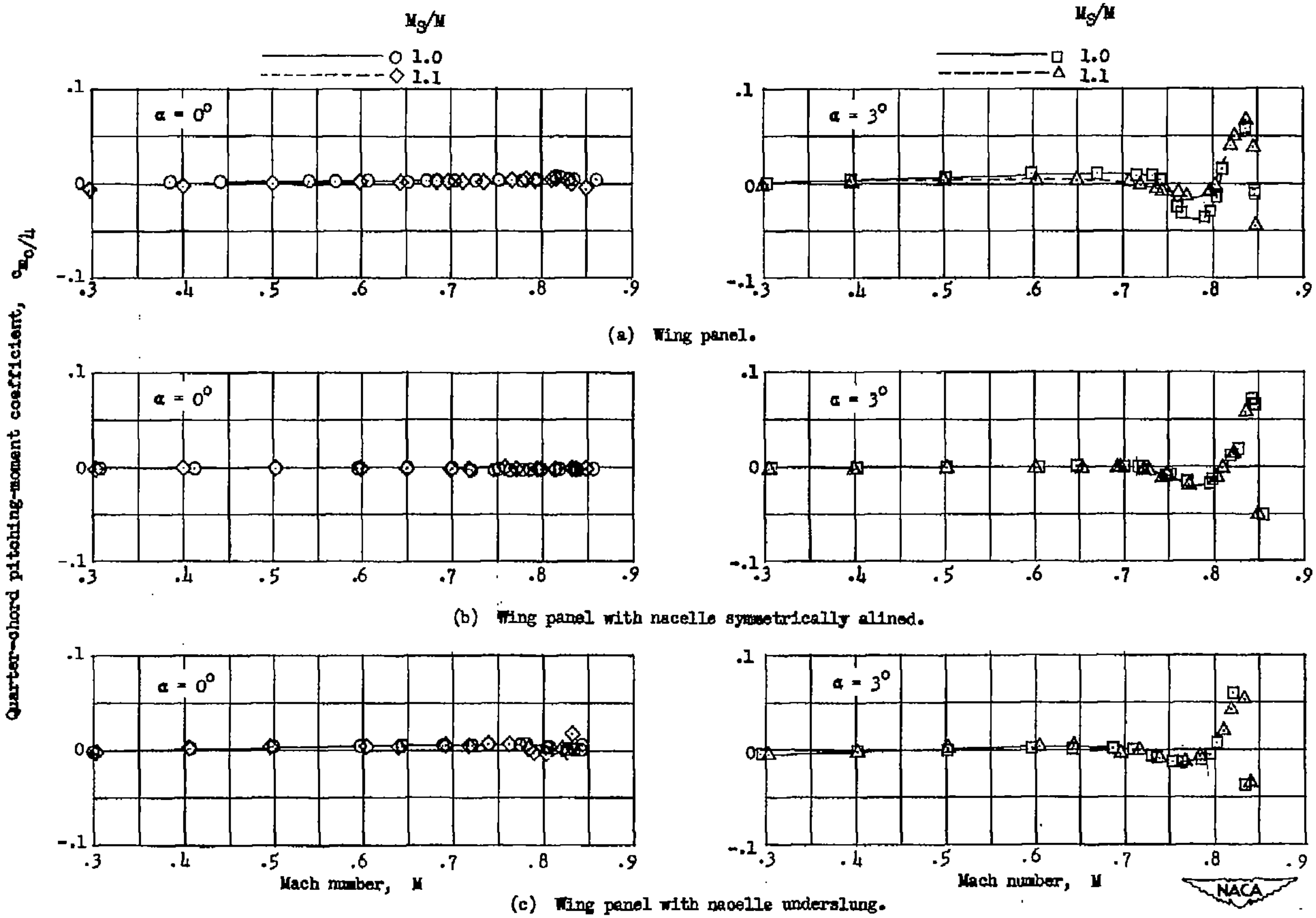
(b) Wing panel with nacelle symmetrically alined.

Figure 3.- Continued.



(c) Wing panel with nacelle underslung.

Figure 3.- Concluded.

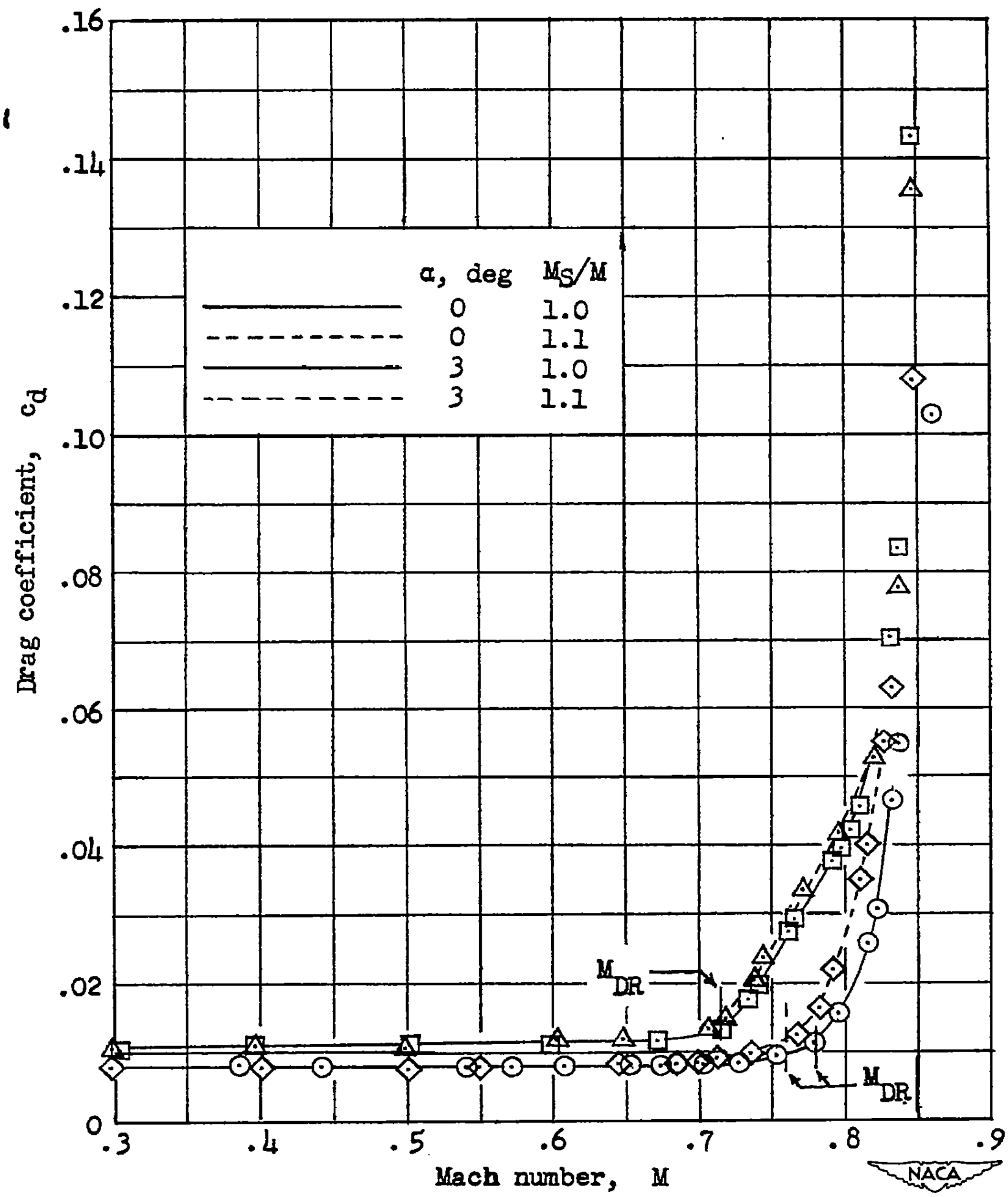


(a) Wing panel.

(b) Wing panel with nacelle symmetrically alined.

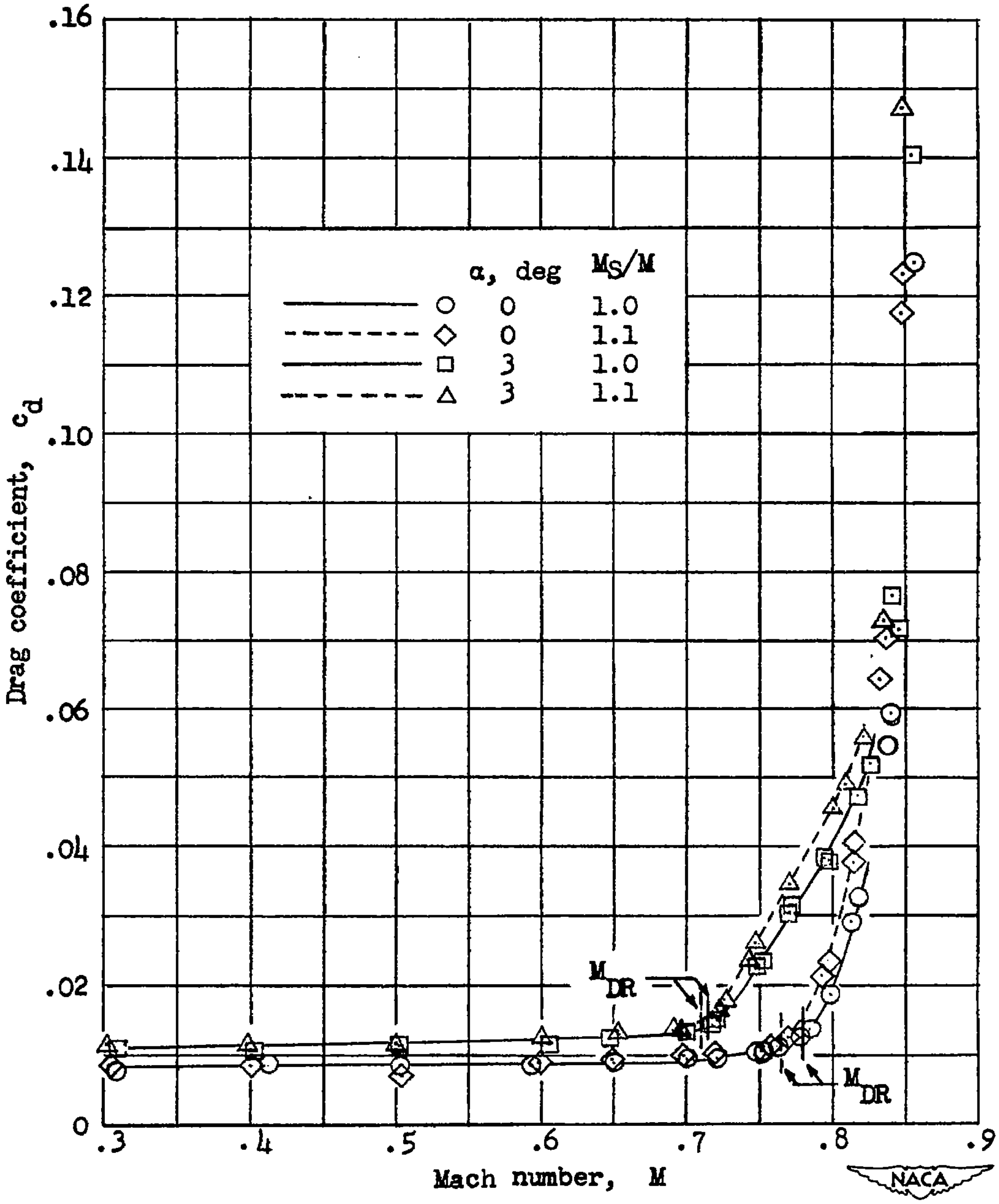
(c) Wing panel with nacelle underslung.

Figure 4.- Effect of slipstream on pitching-moment coefficient.



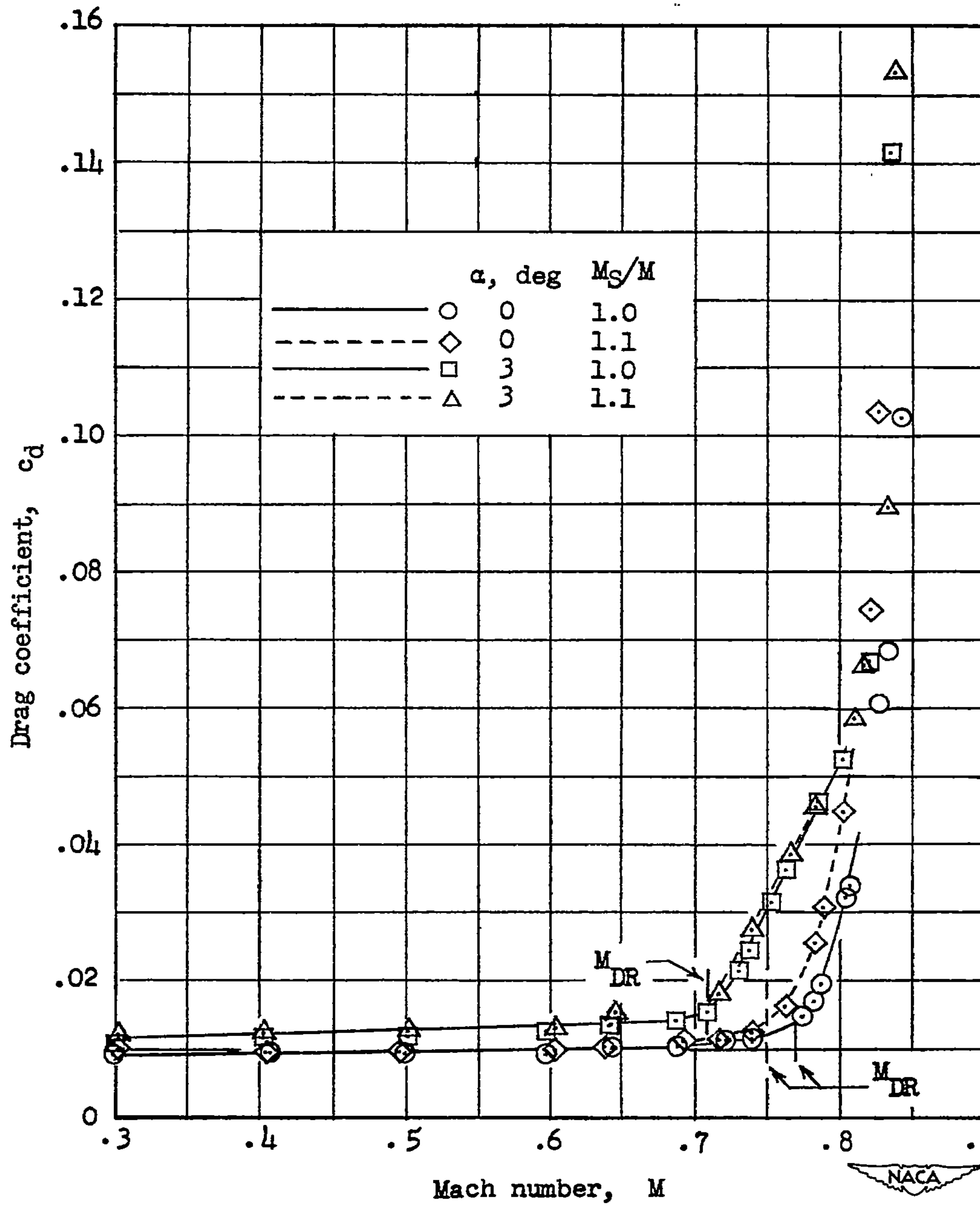
(a) Wing panel.

Figure 5.- Effect of slipstream on variation of drag coefficient with Mach number.



(b) Wing panel with nacelle symmetrically alined.

Figure 5.- Continued.



(c) Wing panel with nacelle underslung.

Figure 5.- Concluded.